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ORIGINAL PAPER

Fern diversity and biomass at Chilapatta reserve forest of West Bengal Terai Duars in sub-humid tropical foothills of Indian eastern Himalayas

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Abstract: We documented the status of fern diversity, biomass and carbon accumulation at Chilapatta Reserve Forest in Cooch Behar Wildlife Division, West Bengal. Stratified random nested quadrat sampling was adopted for analyzing the qualitative and quantitative characters. Nineteen fern species were recorded, of which two are yet to be identified. Identified species were of eight families and nine genera. Highest and lowest frequency recorded were 25.44 and 0.19 while relative frequency varied from 3.16 to 12.25. Fern density ranged from 93 to 13,403 individuals·ha^{-1}. Most of the species were widely distributed. IVI values ranged from 7.54 to 37.45. The above ground portion of ferns accumulated the major portion of biomass and carbon.

Keywords: Chilapatta forest; fern; diversity; biomass

Introduction

Biological studies of ferns have generally been conducted on one or a few species and commonly at a fine geographical scale or to scrutinize subsets of species such as epiphytes or rare taxa. For management purposes and in most plant biological studies, forest communities are normally defined using the composition of vascular plants in the canopy and under-storey vegetation (Roberts et al. 2005). Ferns once dominated terrestrial plant communities over the entire globe and are still present in most terrestrial ecosystems. Fern is the only non-flowering plant (pteridophytes) considered to be the primitive vascular plant group which is distributed all over the world (Chapman 2009). More than 1200 species of fern and fern allies have been reported from India (Dixit 1984; Chandra 2000). Being a group of lower plants, they are always neglected and their useful aspects are largely ignored. Very little attention has been given to the utility of pteridophytes though they possess economic importance and medicinal value as well. It is fern allies and ferns which have now been reported as valuable drug yielding plants (Shil and Choudhury 2009). Possibly Caius (1935) was first to describe the medicinal utility of ferns of India. However, no attempt has been made to model fern distributions based on environmental characteristics or to investigate broad scale patterns in fern diversity for the terai zone of West Bengal. Kaushik and Dhiman (1995) published a compiled account on common medicinal pteridophytes of India. Dutta Choudhury and Bhattarcharya (1996) reported *Dipteris wallichi* from Hailakandi district of Assam. Das (2007) reported fern and fern allies of Tripura. The diversity patterns of ferns are not as well documented as those of the gymnosperms. The terai Duars region of West Bengal is one of the most biodiversity rich areas in India and Chilapatta Reserve Forest is one of the most biodiverse areas of the Terai Duars (Anonymous 2001). However no study has been carried out in the terai zone West Bengal to document fern diversity and its role in carbon sequestration. Therefore the present study was a preliminary attempt to document the fern diversity of this region.

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Materials and methods

Study area

The study was carried out from March 2007 to March 2009 at Chilapatta Reserve Forest under Cooch Behar Wildlife Division in the terai zone of West Bengal which is located at the northern fringe of the state in the foothills of the sub-Himalayan mountain belts. The forest type ranges from tropical wet evergreen to

tropical moist deciduous forest (Champion and Seth 1968). The study area is located at 26°32.85'N and 89°22.99' E measured with GPS (Garmin-72). Altitude of the area was 47 m above MSL. The soil of the terai zone is high in organic carbon and available nitrogen, medium in phosphorus and potash with acidic reaction. The soil structure at 0−30 cm has 70% sand, 19% silt and 11% clay (Paul 2004).

Methodology

Random quadrate sampling was adopted for analyzing fern phytosociology. A total of 285 quadrats measuring 1 m × 1 m were marked for sampling of ferns and climbers. The quadrats were marked in such a way that they were evenly distributed throughout so that they represented the total forest in the study area (22 km2). Identification of fern specimens was done in the field as far as possible. The unidentified voucher specimens were taken for identification either to Taxonomy and Environment Biology Laboratory, Department of Botany, University of North Bengal, Siliguri or to National Herbarium, Shibpur Howrah.

For each quadrat, the fern community was studied for its qualitative and quantitative characters following standard methods (Raunkiaer 1934; Cottam and Curtis 1956; Mishra 1968; Sagwal 1995). Qualitative characters like structure and composition (stratification, sociability, occurrence/presence, function, leaf shape and texture) were described by visual observation. Visually the sociability or the nature of grouping of species in the forest was categorized as species growing singly, in patches, in colonies and intermixed. Species were also classified according to their leaf shape and texture.

Quantitative characters including frequency, relative frequency, Raunkiaer's law of frequency, density, relative density, abundance, relative abundance, importance value index (IVI) and distribution pattern were estimated. Abundance is ratio of total number of individuals of a species recorded to the number of quadrates in which the species occurred. The Raunkiaer's law of frequency states that numbers of species of a community in five 20% classes are A, B, C, D and E distributed as 0−20%, 20%−40%, 40%−60%, 60%−80% and 80%−100%, respectively (Raunkiaer 1934). Commonly used diversity indices were adopted, including species richness, species diversity index (Menhinick 1964) concentration of dominance (Simpson 1949), Shannon-Wiener diversity index (Shannon and Weaver 1949; Shannon and Weiner 1963) and species evenness index (Pielou 1975). All ferns from 1 m × 1 m quadrats were uprooted to measure their fresh weight separately for roots and above ground parts. Permission was received from the authorities of State Forest Department to harvest the samples. The total biomass was converted into carbon content by multiplying by a factor of 0.45 (Woomer 1999).

Results and discussion

Diversity indices

A total of 19 species of ferns were recorded from the Chilapatta Reserve Forest with two non-identified species (Table 1). The identified species represented eight families and nine genera. The dominant families were Pteridaceae, Lygodiaceae and Thelypteridaceae with 5, 4 and 3 species, respectively, while 5 families were each represented by single species. The genus Pteris had the maximum of five species, followed by Lygodium with four species, while Cyclosorus had two species and six genera each had single species.

Table 1. Qualitative characters of ferns

Sl. no.	Scientific name	Family	Sociability	Occurrence/ presence	Function	Leaf shape	Leaf texture
1.	*Diplazium esculentum* (Koenig ex. Retz) SW	Athyriaceae	c	s	e	Q	z
2.	*Dryopteris sikkimensis* (Bedd.) O. Kuntz	Dryopteridaceae	c	s	e	Q	z
3.	*Helminthostachys zeylanica* (L.) Hook	Helminthostachyaceae	c	s	e	Q	z
4.	*Lygodium flexuosum* (L.) Sw.	Lygodiaceae	c	s	e	Q	z
5.	*Lygodium japonicum* (Thunb.) Sw.	Lygodiaceae	c	s	e	Q	z
6.	*Lygodium microphyllum* (Cav.) R. Br.	Lygodiaceae	c	s	e	Q	z
7.	*Lygodium circinatum* (Brum.f.) Sw.	Lygodiaceae	c	s	e	Q	z
8.	*Angiopteris evecta*	Poaceae	p	s	e	Q	z
9.	*Colysis decurrens* (Blume) Panigr[e]	Polypodiaceae	p	s	e	Q	z
10.	*Pteris aspericaulis* wall	Pteridaceae	c	s	e	Q	z
11.	*Pteris biaurita* L.	Pteridaceae	c	s	e	Q	z
12.	*Pteris himalayensis* Ghosh	Pteridaceae	c	s	e	Q	z
13.	*Pteris linearis* Poir.	Pteridaceae	c	s	e	Q	z
14.	*Pteris semipinnata* L.	Pteridaceae	c	s	e	Q	z
15.	*Cyclosorus holttumii*	Thelypteridaceae	c	s	e	Q	z
16.	*Cyclosorus mantoniae*	Thelypteridaceae	c	s	e	Q	z
17.	*Pronephrium nudatum* Roxb.	Thelypteridaceae	c	s	e	Q	z
18.	Un -1	-	c	r	e	Q	z
19.	Un -2	-	c	r	e	Q	z

Notes: c is colony, p is patch, s is seldom present, r is rare, e is evergreen, Q is thalloid, z is membranous. Un is unidentified.

Species diversity in tropical areas varies greatly from place to place mainly due to variation in biogeography or local landscape conditions (e.g., soil type, topography), habitat and disturbance (Whitmore 1998; Fajardo and Alaback 2005). The local landscape was dominated by trees and ferns inhabiting sites below gaps in the tree canopy and under the partially shaded sites below the tree canopies.

Other diversity indices like Menhinick's diversity index, concentration of dominance, Shannon-Wiener diversity index, evenness index and density (individual's·ha^{-1}) are presented in Table 2. The fern diversity index or Menhinick's index was low at 0.34. The index considers the total number of species and total number of individuals of all the species. Based on this index it can be stated that the fern assemblages found in this forest low in diversity but individual species were frequently present. The concentration of dominance was 0.31. This represents the probability of a species being encountered during sampling (lower value means the chance of encounter is higher). The Shannon-Wiener index is inversely proportional to concentration of dominance and the corresponding value was 1.57. This index is also an expression of community structure and complexity of a habitat.

Table 2. Diversity indices of fern communities of Chilapatta Reserve Forest

Sl. no.	Diversity indices	Value
1.	Species richness	19
2.	Family richness	08
3.	Genera richness	09
4.	Fern diversity index	0.34
5.	Concentration of dominance	0.31
6.	Shannon-Wiener diversity index	1.57
7.	Evenness index	2.49
8.	Density (individuals/ha)	218982

A high index value suggests a more diverse and stable fern community. Fern species in the forest were distributed evenly with a high value of 2.49. The density of ferns was sometimes high and widely variable, at 2, 18, 982 individuals·ha^{-1}. Galav et al. (2005), Srivastava et al. (2005), Dash et al. (2009) also reported the inverse relationship between concentration of dominance and the Shannon-Wiener index as observed in this study. Chilapatta Reserve Forest is a diverse community in which the species are evenly distributed with higher chances of encountering a species during sampling. This was confirmed by the higher values of the species diversity index, concentration of dominance, Shannon-Wiener index, evenness and density. This was because the forest is protected under law as a Reserve Forest or Protected Forest for wildlife and there is little anthropogenic disturbance.

Qualitative characters

The qualitative characters are presented in Table 1. Ferns occurring less frequently were *Helminthostachys zeylanica*, *Lygodium japonicum* and *L. microphyllum* and they represented 89.47 % of the total recorded ferns while the remaining two ferns could not be identified. All fern species grew in colonies. All recorded fern species had thalloid leaves with membranous texture.

Quantitative characters

The parameters for vegetation analysis i.e. frequency, relative frequency, Raunkiaer's law of frequency, density, relative density, abundance, relative abundance, important value index and distribution pattern are presented in Table 3. Frequency of the fern species in the forest ranged from 0.19 to 15% i.e. of all the species, chance of occurrence of an unidentified fern was least while *Diplazium esculentum* occurred most frequently. Similarly the chance of occurrence of *Pteris aspericaulis* relative to all other species of fern was highest with 12.25% while an unidentified fern recorded lowest at 0.42%. The fern community was grouped into two frequency classes as A and B following Raunkiaer's law of frequency (1934) in which 94.74 and 5.26 %, respectively of species were distributed. Density or numerical strength of species per unit area ranged from 92 to 13,403 individuals·ha^{-1}. *Diplazium esculentum* was sparse while *Pteris aspericaulis* was most abundant.

Relative density ranged from 2%–15%. *Pteris aspericaulis* had the highest representation while an unidentified fern species (sl. no. 18; Table 3) had the lowest. Species abundance is numerical strength of species in a sampled area and in the present study it was lowest with 0.6 for an unidentified fern species (sl. no. 19; Table 3) and highest for *P. aspericaulis* (8.9). Abundance, however did not give a total picture of the numerical strength of a species because it considers only the quadrats of occurrence of a species. Therefore relative values to total abundance of all the species in all sampled quadrats are indicative of actual numerical strength of a species. In the present study, three species recorded the lowest (2%) while *P. aspericaulis* had highest (10%) relative to all other species recorded. The IVI of fern community ranged between 0.89–37 for an unidentified fern to *Pteris aspericaulis*. IVI helps in understanding the ecological significance of the species irrespective of vegetation type: greater IVI values indicate greater ecological significance of the species in a particular ecosystem. One species of fern was regularly distributed and five were random while 13 (sl. no.) were contagiously distributed. The abundance to percentage frequency ratio provides information about the nature of distribution of species. Values <0.025, 0.025–0.05 and >0.05, indicate regular, random, and contagious distributions, respectively (Cottam and Curtis 1956).

Biomass and carbon accumulation

Estimates of rate of biomass accumulation and partitioning by ferns at the time of observation are given in Table 4. The total fern biomass accumulated at Chilapatta Reserve Forest was 0.540 mg·ha^{-1}. The contribution of foliage or above ground biomass was 0.42 mg·ha^{-1} while rest was contributed by the roots. Biomass partitioning is an important driver of whole-plant net carbon gain and has a direct influence on future plant growth and reproduction (Evans 1972). Knowledge of biomass allocation between vegetative and reproductive compartments will greatly

improve our understanding of plant life history strategies (Westoby et al. 2002; Niinemets et al. 2007; Pickup et al. 2005), and will improve the silvicultural techniques efficiently to manage a forest sustainably. The biomass of a fern community can be used for storage of carbon and carbon cycling at a regional as well as global level, and can be estimated for planning viable options to mitigate CO_2 increased climate change.

Table 3. Quantitative characters of ferns

Sl. no.	Scientific name	Frequency	Relative frequency	Frequency class	Density (individuals/ha)	Relative density	Abundance	Relative abundance	Importance value index	Distribution pattern
1.	*Diplazium esculentum*	25	4	B	92	5	4	10	19	R
2.	*Dryopteris sikkimensis*	11	4	A	3052	3	8	4	12	C_1
3.	*Helminthostachys zeylanica*	10	5	A	2491	6	4	7	18	R_1
4.	*Lygodium flexuosum*	10	5	A	9263	4	4	3	13	R_1
5.	*Lygodium japonicum*	11	6	A	6175	4	8	5	15	C_1
6.	*Lygodium microphyllum*	9	6	A	1719	6	6	4	16	C_1
7.	*Lygodium circinatum*	7	6	A	1403	5	2	2	13	R_1
8.	*Angiopteris evecta*	7	4	A	11824	5	6	7	17	C_1
9.	*Colysis decurrens*	5	5	A	3649	5	4	5	16	C_1
10.	*Pteris aspericaulis*	6	12	A	13403	15	5	10	37	C_1
11.	*Pteris biaurita*	15	4	A	13403	4	8	3	11	C_1
12.	*Pteris himalayensis*	12	5	A	10736	6	8	6	17	C1
13.	*Pteris linearis*	10	5	A	8701	5	8	2	12	C_1
14.	*Pteris semipinnata*	10	4	A	5438	5	5	4	13	R_1
15.	*Cyclosorus holttumii*	7	7	A	4701	4	5	5	16	C_1
16.	*Cyclosorus mantoniae*	8	4	A	4210	5	5	6	16	C_1
17.	*Pronephrium nudatum*	6	3	A	6350	3	5	4	11	C_1
18.	Un -1	3	3	A	2070	2	2	2	7	C_1
19.	Un-2	0.2	4	A	3649	3	0.3	3	10	R_1

Notes: R is regular, R1 is random, C_1 is contagious, Un is unidentified. A, B are frequency classes described by Raunkiaer (1934). The Raunkiaer's law of frequency states that numbers of species of a community in five twenty per cent classes are A, B, C, D and E distributed as 0–20, 20–40, 40–60, 60–80 and 80–100%, respectively.

Table. 4 Fern biomass and carbon stock ($mg \cdot ha^{-1}$)

Index	Foliage	Root	Total
Biomass	0.420	0.120	0.540
Carbon stock	0.190	0.053	0.243

Carbon accumulation estimates and partitioning of ferns at the time of observation are given in Table 4. The total carbon accumulation by ferns was 0.243 $mg \cdot ha^{-1}$. The foliage or above ground portion contributed almost 80% and rest was contributed by the roots. Carbon stock is intricately linked with site quality, nature of land use, choice of species and other silivicultural practices (Swamy et al. 2003). These factors ultimately influence plant growth, which is reflected in its biomass (0.54 $mg \cdot ha^{-1}$) and its proliferation as evidenced from its population (218,982 ha^{-1}). This is because of the site factor i.e. tropical moist deciduous with soil having high organic carbon and available nitrogen and heavy precipitation (2942 mm annual rainfall), high mean monthly relative humidity (69.0%–91.5%) and optimum temperature (9–32°C). These site quality factors supported luxuriant growth supporting biomass accumulation and carbon storage. It is well known that many factors may affect the carbon budget of an ecosystem: biotic features including the leaf size, photosynthesis rate, plant architecture and type of forest (evergreen or deciduous), and abiotic features such as solar radiation, temperature, water supply, soil property and the length of growing season.

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